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[Despatch Abstract.]

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A NOTE ON THE TUNGABHADRA DAM-SITE AND PROJECT.

(June 1947)

By

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INTRODUCTION

Numerous surveys have been made since 1861 for storage works and canals in the middle reaches of the Tungabhadra river; the most recent survey was in 1942

The present site near Malapuram (15° 16' : 76° 20' 45") was originally selected in 1902-03 by Mr. Mackenzie, the then Superintending Engineer. It was considered to be the most promising of the many sites examined as one possessing strong foundations and good abutments. This site lies about 3½ miles south of west of Hospet about 3 furlongs west of Malapuram.

Here the Tungabhadra river is about 1375 feet wide and flows from south-west to north-east between two high spurs of the Sandur range of hills. These spurs are composed of a great thickness of ferruginous quartz-schists and of ferruginous quartzites; they are underlain by the epidiorite schists which are so well exposed in the Tungabhadra valley. In this valley, these rocks which form a part of the Sandur synclinal basin occupy an inverted position on account of a local thrust; this has given rise to a local reversal of the normal easterly dip of this limb of the syncline.

Engineering details.

The proposed reservoir would have a capacity of about 113, 126 m.c.ft. The catchment area covers about 10,880 sq.miles and it has an annual rainfall of 23 inches. The maximum discharge in this area is estimated to be about 650.000 cusecs.

The dam which is proposed to be built here would be of the masonary gravity type; it would be aligned N 55° W. to S 55° E. It lies partly in British territory and, partly within Hyderabad State. The main section of the dam including the length of the spillway would be about 8398 ft. (of which 6588 ft. is of masonry, but if the composite dam on the Hyderabad side be also included it would be about 10,470 ft.

The R.L. of the top of the dam would be 1642 ft., of the full supply level 1628 ft. and of the bed of the river 1524 ft. The width of the top of the dam would be 22ft. and of the base about 82 ft. The probable static pressure at the base of the dam would be about 10.21 tons per sq. ft.

SUMMARY OF THE GEOLOGY OF THE DAM-SITE

This dam-site has been examined in the past by a number of geologists including Messrs. Bruce Foote, Middlemiss, Vinayak Rao and Mukherjee; in 1941, Dr. M.S. Krishnan and Dr. C. Mahadevan examined this site and submitted a full report on it and this is published in the Journal of the Hyderabad Geological Survey, Vol. IV, pt. 2, pp. 51-65 (1945).

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There is a general consensus of opinion about the great strength and durability of the foundation rocks and also about the favourable upstream dip of these rocks. But Messrs. Bruce Foote and Middlemiss have drawn pointed attention to certain features; the former about the possible occurrence of a fault-like close to this dam-site and the second authority about the crushed and sheared nature of the contact rocks at the junction of the pegmatities with the epidiorites.

"The epidiorite constitutes the country-rock of this area, but a few narrow ribbons of ferruginous quartziteschists and reefs of pegmatite cut through the epidiorites and either interest or lie in the vicinity of the dam-line... They (Epidiorite-schists) are fine to medium grained in texture and structure is schistose because of the general parallel disposition of the amphiboles, the rock is hard and tough and breaks generally along joints and only occasionally parallel to the schistosity" * 1B. ⊗ and show extreme weathering even at the surface. Though

The epidiorite schists and the haematite quartzites are highly jointed rocks and the former shows a tendency to part along the schistosity planes.

My recent examination of the dam-site and foundations trench had shown:-

1. That there is a minor zone of disturbance near about bore-hole No.1 within the last 160 ft. of the Madras and of the dam-line and another but smaller zone of disturbance near the eastern abutment of the composite dam at the Hyderabad end close to bore-hole No. 25.

That the contact-planes between the epidiorites and the pegmatities are generally badly crushed and sheared and have resulted in a mass of highly fragmental and comminuted rocks. This is, however, a small narrow zone which can be grouted effectively

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1 Rec. Geol. Surv. India., Vol.XIX, pt. 2, 1886, p. 106.

2. A report of the Madras Government on the Tungabhadra project Vol.II, appendix 19, (1934)

B. Journal of the Hyderabad Geological Survey, Vol. IV, pp. 51-66. (1945)

3. That the hard layers of epidiorites are interbedded in places with soft schistose rocks as near L.S.425, 1910, 5570 and especially at and close to either abutment (of the main section of the dam).

4. Thin beds of haematite quartzites lying over the epiriorites were also met with in some portions of the damsite on the Hyderabad side. They were best seen near:- L.S. 4395, between 5320 and 5680 and at 5870.

5. The epidiorites and ferruginous quartzites are highly jointed and fissured all along the dam-line and they require a special treatment to serve as a safe foundation rock. Dr. M.S. Krishnan and Dr. C. Mahadevan in their report have drawn special attention to this and they have suggested that the entire length of the dam-line and its immediate neighbourhood should be systematically grouted with cement under pressure. In agreeing with this view, it is further suggested that the system of "curtain-grouting" should be an intensive one (to fill up all the joints and fissures) and it should be more or less on

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the type of grouting adopted in the Norris dam, Tennessee river, Tennessee, U.S.A. As the bed of the river is rather rocky, it is doubtful whether these numerous fissures and joints would be filled up in due course naturally by silt.

Boring operations.

About 25 bore-holes have been drilled at approximate intervals of 200 ft. and numbered serially from the Madras end. As the bore-cores were rather jumbled up at the time of my visit, I could not study them, but they have been examined in detail by Dr. Krishnan and Mahadevan. They have suggested that the foundations for the dam need be taken down to the following depths at the various points indicated in order to encounter hard rocks:-

Bore-holes 1 to 3	... almost exclusively on epidiorites; the joints disappear 15 to 30 ft. below the collar of the bore.
Bore-hole 5	to be taken down more than 30 ft.
Bore-holes 6 and 7	... to be taken down below 25 or 30 ft.
Bore-hole 8	... Jointed upto 30 ft. and beyond that depth sound.
Boreholes 13 to 18	... the joints at the junction of the pegmatites with the epidiorites should be 'cement-grouted'. Should be taken down below 10 to 15 f
Bore-hole 20	Quite hard-rocks.
Bore-hole 21	... Good foundations within 15 ft.
Bore-holes 22 to 25	... all on good epidiorites.

My recent investigations in the foundation trench had shown that these rocks had weathered in a highly irregular manner, in depth and the information obtained from two consecutive bore-holes cannot always be applied intermediate distances. Thus the cores obtained from bore-hole No.2 suggested that solid hard rocks could be expected to occur below 14 ft. i.e. at R.L. 1558 ft. But actual excavation had shown that at a spot about 45 ft. to the north-west of this bore-hole, the hard rocks lie at much greater depths i.e. much below this datum of 1558ft. and at 1558 ft. only soft rocks are to be found. This being the case, it is suggested that in order to decide whether the foundations had been carried deep enough, a periodical geological examination of this dam-site should be made as excavation proceeds. At the time of my visit only some portions of the dam-line were being excavated; there were no excavations at the following places:-

Between	L.S.0	and 100 f
	"980	" 1100 "
	"2165	" 2549 "
	"2980	" 3630 "
	"4152	" 4400 "
	"5120	" 5520 "

The details of the excavation and of the strata exposed on the sides and floor of the trench are tabulated below

Location Longitudinal	Objective datum.	Depth reached	Depth Still to	Nature of rocks (in trench floor)

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Section (in feet)		ft. below collar of bore of below surface ft.	reach below collar of bore or below surface ft.	
Madras Side.				
0		nil		
250		nil	87	
1100		30	60	Crushed and buckled strata.
1160 (B.H.I.)	1558	15	25	Hard epidiorites Dip 60 WSW
1240		10	20	" "
1300		14	13	
1380 (B.H.2)	1558	12	7	Soft epidiorites
1425	1558	12-1	20	Soft epidiorites
1588 (B.H.3)	1535	13	15-16	Fairly hard jointed epidiorites
780 to 980		11	22	Decomposed Pegmatites
980			nil	
1180 (B.H.6)	1526	16	24	Decomposed Pegmatites
1375 (B.H.7)	1539	8	7	Hard Pegmatites
1565 (B.H.8)	1514	6	29	Partly on Pegmatites and partly on soft epidiorites.
The section between 1650 and 1740 should be very heavily grouted				
1650		10		Decomposed and jointed epirorites
1740		7	8	Hard jointed epidiorites
The section between 1650 and 1740 should be very heavily grouted.				
1910 (B.H.10)	1539	11	10	Fairly soft jointed epidiorites
2089		11	10	do do
2165	1504	nil		Black cotton soil
2360 (B.H.12,	1510	nil		Hard epidiorites Dip 50 WSW
Hard epiriorites between 2315 and 2549.				
2549 (B.H.14)	1510	nil		Brownish grey sandy alluvium
2730 (B.H.14) (Coffer dam section)	1510	5	13	Fresh hard greyish black epidiorites. Dip 40 SW
2980 (B.H.15)	1510	nil		Highly jointed but less massive epidiorites. dip 45 Sw
Between 3000 and 3400 Disturbed beds some showing reversal of dip-the fissured rocks should be grouted only wherever necessary.				
3230 (B.H.16)	1510	nil		Fresh hard greyish black epidiorites
3430 (B.H.17)	1510	nil		do do

1.	2.	3.	4.	5.

HYDERABAD STATE SIDE .

+ 3630 (B.H.18)	1510	Practically nil		Fresh hard greyish black epidiorites Dip 45° SSW
+ 3830	1510	5	10	Decomposed fairly soft pegmatites
+ 4030 (B.H.20)	1510	8	10	Do do
+ 4152		6	—	Pegmatite reef crosses dam-line
Between + 4152 and + 4395				Badly shattered epidiorites with reversed dip in some beds.

This section between + 4152 and + 4395 should be heavily grouted.

4000		nil	nil	jointed epidiorites with upstream dip.
Between + 4500 and + 4800		10 at 4650		Hard fresh sparsely jointed greyish black epidiorites
Between + 4880 and + 5100		10		Jointed brownish grey epidiorites Dip 70° SW
+ 5025 (B.H.22)	1527		..	Highly weathered and jointed epidiorites
Between + 5120 and + 5370			..	do do
+ 5370 and + 5520			..	Highly shattered epidiorites
+ 5520 to + 5570			..	very soft rocks Dip 35° WSW

The whole section between + 5025 and + 5570 should be heavily grouted.

570		25		Very soft and highly weathered and decomposed epidiorites similar to that exposed within the last 100ft. of the Madras end. But the rocks are not disturbed and they dip (35° WSW) uniformly upstream. These soft rocks are intercalated with thin beds of hard but jointed epidiorites.

SIMILAR SOFT ROCKS ARE ALSO FOUND EXPOSED BETWEEN +5520 AND 5680 ft. AND THIS SECTION SHOULD ALSO BE VERY CAREFULLY GROUTED IN ORDER TO FILL UP ALL JOINTS AND FISSURES. FURTHER, SPECIAL CARE SHOULD BE TAKEN THAT THE EXCAVATIONS ARE TAKEN DEEP ENOUGH TO ENCOUNTER A GOOD THICKNESS OF HARD ROCKS AND THE DAM SHOULD BE FOUNDED BETWEEN L. S ££") AND £'&) ONLY ON SUCH HARDER ROCKS. THE FOUNDATIONS HERE SHOULD BE TAKEN AT LEAST FIVE FEET INTO SUCH HARD ROCKS..

+5870

Between L.S + 5870 and + 10,470, there is, so far, no excavation.

Suggestions.

(1) Since the dam is proposed to be aligned more or less parallel to the foliation strike of the schistose rocks and since the dip is also upstream, there is no serious geological objection to this dam-line but certain precautions have necessarily to be taken in the construction of this dam. They are:-

(a) The foundation of the dam should be taken down at least five (5) feet into the hard solid rock and the base of the dam should be suitably anchored. This anchoring would be quite necessary at the Madras end between L.S.0. and 160 ft. of the present alignment of this dam-line is retained finally. The type of anchoring adopted in the Cheurfas dam in Algeria is perhaps the most suitable one.

(b) The width of the base of the dam should be made the maximum possible beneath the following co-ordinates; here it should be in any case, greater than the 82 ft. width which is proposed to be adopted for the whole dam-line.

Between L.S.	...	0 ft.	and	160 ft
" "	...	380 "	"	500 "
" "	...	1100 "	"	1600 "
" "	...	1650 "	"	1740 "
" "	...	3000 "	"	3400 "
" "	...	4200 "	"	4300 "
" "	...	5370 "	"	5870 "

(c) The last 160 ft. of the Madras end of this dam-line apparantly lies within a minor zone of disturbance. Here, between L.S. + 100 ft. and + 160 ft., there is exposed in the dam-line a zone of badly crushed, buckled and fractured schistose rocks, which have become so soft at the surface as to yield easily to the hammer.

As the excavations in this part of the trench had not progressed deep enough, it is difficult to say whether thi disturbance is due to a minor fold or owed to a small fault A small minor fault of no great throw or extent crosses thi dam line obliquely between L.S. + 100 ft. and + 160 ft. The fracturing and buckling of the beds is most intense along this plane; such soft schistose beds are best seen on the

northern.....

northern face of the dam-line opposite to B.H. (1) and on the E.S.E. face near L.S. +100 ft. It is hard to predict the vertical extension of these soft beds in depth and also whether they would die out in depth or not.

Between L.S. +160 ft. and L.S. +300 ft. there is a thick band of a fairly hard epiriorite-schist with a thin capping of ferruginous-quartzite, exposed in the floor of this trench. It courses approximately NW-SE and crosses this dam-line obliquely near about L.S. +160 ft. i.e. close to B.H. (1). Whereas this band is exposed on the northern face of this trench between L.S. +160 ft. and +300 ft. it is exposed on the southern face of it near L.S. +100 ft.

If by a deep boring it is found that these soft schistose rocks extend very deep, then it may prove costly to take the foundations to rest on the hard rocks. In such a contingency it may prove highly advisable to realign the dam-line in such a way as to ensure that this portion of the foundations also rest on this thick hard epiriorite-band; the dam-line could be shifted to a few tens of feet to the S.W. But before deciding on this it is necessary to prove th total vertical extension of these soft rocks and the horizon and thickness of the hard solid rocks if any, occurring beneath these soft rocks. For this purpose the following measures are suggested

A deep pit 6 ft. x 4 ft. x 45 ft. should be dug at an early date in the bottom of this trench just north-west of L.S. + 100 ft; if the soft rocks are still exposed in this new pit, then a shallow boring (75 ft. deep) should be put down in the bottom of this new pit.

(2) Another shallow bore hole (100 ft. deep) should be drilled between L.S. 0 ft. and +100 ft.

(3) Two samples of the soft rock now exposed in the floor of this trench near L.S. +100 ft. should be tested for the crushing strength along two directions both parallel to and at right angles to the plane of schistosity.

If such borings go to indicate (i) that this minor fault dies out in depth, (ii) that the soft schistose rocks referred to above, do not extend very deep underground and (iii) that any solid rocks found underground are of considerable thickness, then all that would be necessary is only to take down the foundations at least 5 ft. into the hard solid rock and as a further precautionary measure to tie the abutment into the hillside by means of a corewall at the Madras end. Further, in order to minimise the water-thrust at the Madras and of the abutment, it would also be advantageous to build a wide apron of rockboulders. On the Hyderabad side a good thickness of such soft decomposed rocks are also found between L.S. +5520 and +5870, but here are all uniformly dipping upstream; in places they are intercalated with thin hard bands of epiriorites.

(d) As both the epiriorites and the ferruginous quartzites are highly jointed and fissured along the entire length of this dam-line it would be absolutely necessary to systematically grout with cement under pressure the whole length of this dam-line and its immediate neighbourhood. The intensive system of curtain-grouting adopted in the Norris dam, Tennessee river, Tennessee, U.S.A. should be preferably

followed.....

followed here also. The following places are especially bad and require careful attention:-

Between L.S.		and	+160 ft.
"	300 "	"	+ 425 "
At	780 "		
Between L.S.	1100		1600
"	1650		1740
"	4152		4395
"	5025		5570
"	5570		5870

The contact-planes between the epiriorites and the pegmatites have been noticed to be planes of weakness and as such all such contact-planes should also be heavily grouted with cement throughout their length in order to fill up all fissures and voids;

(e) If it is found after boring deep that there is no need to change the alignment between L.S. 0 ft. and +160 ft. at the Madras end, then it maybe advisable to shift the level channel which is proposed to be constructed at this flank to the N.W. of bore hole (1) so as to lie over the hard strata.

Materials for dam-construction

About a year back (28.8.1946) Dr. M.S. Krishnan conducted a survey of the available materials for dam construction.

At the request of the Engineering authorities a re-examination of the resources of sand, clay, brick-clay, stone (granite) and of kankar and limestone available within a reasonable and economic distance of this damsite was also made.

For the construction of this dam, the following approximate quantities of materials would have to be used on the Madras side alone; the quantity of each material would be dependent upon the kind mortar which is finally decided to be used here.

	If lime-surki is used	If cement mortar is used
Sand	2½ m. cft.	10 m.cft. "
Surki	7	
Cement	Nil	2½ "
Limestone	5	nil

Large supplies of good quality sand, clay, brickclay and stone (granite) could be had within an economic distance of this dam-site but there appears to be no large source of supply of limestone or kankar in the region.

Sand

Coarse, clean, sub-angular sand very suitable for use in the preparation of mortar is now being obtained from the Chikka Hagari river, nearly 20 miles distance from this dam-site. A further quantity of such sand can also be had near

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milestone....

milestone 45 on the Hospet-Hubli road; this source is about 5 miles distance by road. There is a nearer source in the Gauripura Vanka. This lies about 1½ miles almost due south of this site. There is a good thickness of sand in the bed of this nala in the lower reaches, for about a mile northwest of the crossing of a cart track from this dam site to Tarahalli village. (15° 14' : 76° 19' 45"). Here the Vanka is about 100 ft. wide and assuming that the average thickness of the sand in the bed of this Vanka is about 2 ft., a million cubic ft. of sand can be had from this source. The sand of this Vanka is of a brownish-gray, coarse, sub-angular variety but unfortunately it is much admixed with disintegrated pieces of phyllites, epiriorites and iron ores etc. As it may be possible to separate the ferruginous impurities by powerful electromagnets and the other impurities by thorough washing, samples of this sand have been collected for further tests.

On account of the rocky nature of the bed of the Tungabhadra river at and near to this site, it would not be possible to obtain large supplies of sand from this river itself.

Brick-clay

Fairly large deposits of good quality brick-clay occur in the following localities:-

(i) Within 2-3 furlongs west of south of Hospet Inspection Bungalow close to a channel, and on either side of the cart-track connecting Chittanedigi village with the main Hospet-Narayanadevanakere road. Here good brick clay occurs superficially within the top 1½ to 2 ft.

(ii) A large deposit of a highly plastic fine red (chocolate) brown) clay, about 12ft. thick lies in a dammed-up valley between the Hospet-Hubli road and Rajapuram village (15° 14' 76° 23' 30"). This is locally known as the Rayarakeri tank.

Clay.

The suitability of certain occurrences of clay near this site for "surkhi" manufacture was also investigated, "Surkhi" is generally made by pounding old bricks or the brick bats obtained from kilns. When these are not available it is made from round balls of clay specially prepared and burnt for the purpose.....The presence of lime in the clay burnt has a great influence on the manufacture of surkhi. Clays containing 10 to 20 per cent make the best surkhi if they are under-burnt. Those containing little or no lime have to be thoroughly burnt to bring out their best qualities. Clays containing a large proportion of sand are not so suitable for making surkhi as those which having more alumina in their composition, are greasy to the touch. "(Roorkee treatise on Civil Engineering, Section1, Building Materials", 1928.

Malapuram camp stands on a thick layer of black cotton soil. Black cotton soil is found to be fairly extensive both to the north and north-east of Malapuram village. A layer of greyish black plastic clay, 1-2 ft. in thickness occurs beneath this type of soil at a depth of 5 to 6 ft. As usually small nodules of kankar occur above this clayey layer, it is probable that this type of clay may prove, on testing, to be quite

suitable.....

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suitable for surkhi-making. The fine plastic red (chocolate-brown) clay occurring in the bed of the Rayarakere tank to the northwest of Rajapuram village has already been mentioned above. This tank-bed is about 1.3/8 miles long and about ½ a mile wide. The average thickness of the clay-bed is about 12 ft. but it may be much thicker in the middle portions of this tank. This clay does not appear to carry any lime at least in its free state, but as it is highly greasy to the tough, it may be, perhaps utilised for surkhi-making after a thorough burning; this has also to be tested. For about ½ a mile to the west of this dam-line along the foreshore of the Tungabhadra river there is a good deposit of grey coloured clay (somewhat arenaceous in character) lying in a zone 50 to 100 ft. wide and below a depth of 2 to 3 ft. This layer of clay is about 1 to 2 ft. thick on the average. This type of clay can be traced to extend for ever 1¾ miles almost continuously to the south-west upto Kundaguddi village (15° 15' : 76° 19'), especially in the 'doab' between the Raju channel and a small tributary of the Tungabhadra river. Through the composition of this clay may be somewhat be somewhat more arenaceous than that of the other two varieties described above, it may yet prove suitable for surkhi-making and this should also be tested.

Stone.

Large quantities of good quality granite most suitable for building purposes are found in the hills between Rasavanadurgam (15° 19' : 76° 23' 30") and Nimbapuram (15° 20' : 76° 29'), around Kamalapuram village (15° 18' : 76° 28½') and in the Billakallu R.F. But these occurrences are about 10 miles distant from this dam site.

The following occurrences are found nearest to this site:-

(i) A small quarry lying about ¾ furlong almost due south of milestone 363/0 on the Hospet-Bellary road. This is fine grained sparsely jointed grey granite which is very amenable to dressing. This quarry is about 5 miles from this dam-site.

(ii) A larger occurrence on low ground in an island in the middle of the Tungabhadra river about ½ a mile to the N.E. of this dam-site. There is a low hill (boss) of granite in this island; this is made up of irregularly jointed coarse porphyritic granite intruded by numerous small veins of pegmatite and of quartz. This type of granite will not be suitable for use as a building stonw but can be utilised as random-rubble.

But on the low ground to the east and south-east of this hill (boss), medium-grained grey granites which are only sparsely jointed, are found in a narrow zone about 2 to 2½ furlongs long by 1 furlong wide. Three would yield good building stones. But as they are found on low ground, it would be rather costly to quarry them.

The quarries on hill 2292 on the Hospet Narayanadevanakere road and a number of smaller areas between milestones 360/0 and 363/0 on the Bellary road were also examined. The granites exposed here are usually irregularly jointed and intruded by small veins of pegmatites. They are not suitable for building purposes but can be best used as random-rubble.

Stone for Hearting.

The hard fresh epiriorites which are sparsely jointed and

found in some portions of this dam-line could be used as 'hearting material'

Kankar and Limestone.

A detailed examination of all recorded occurrences of kankar and/or of limestones between this dam-line in the north and Gollalingammanahalli (14° 58' : 76° 40') in the south had shown conclusively that it would be idle to hope to obtain large quantities of good quality kankar or of limestones, for lime manufacture anywhere here. The following areas were examined for this purposes:-

(1) Area lying about ½ a mile north of Jambunathaswami temple. Here a thin capping of kankar is found over gneissi gneissic rocks in a zone 300 ft. X 50 ft. ; the thickness of the kankar layer varies between 1 and 1½ ft. It is purely a local show. According to the P.W.D. authorities, samples of this kankar analysed:-

CaO	.....	49.07 per cent.
Fe_2O_3	.....	2.75 "
Al_2O_3	.....	2.64 "
MgO	.....	trace "
SO_3	.....	0.37 "
Insolubles	.....	17.04 "

(2) On either side of the M. & S. M. Railway line to Bellary between Telegraph posts 168/5 and 168/21-22. [illegible] between Telegraph posts

(a) Between T.P. 168/8-9 to the south of the railway line - good quality kankar is found in a zone 30 ft. X 5 ft. X 1½ ft.

(b) Between T.P. 168/6 and 168/8-9 to north of railway line (at a distance of 50-75 ft. north of this track) there is a small narrow zone of kankar, 500 ft. long 90 ft. wide and 1½ ft. deep running almost parallel to the railway line. The thickest portion of the kankar layer is only 3½ to 4 ft. thick. Pitting has shown that here the layer of kankar lies about 1-2 ft. below the brown soil.

(3) About ½ furlong south of the railway line near T.P. 168/14 - a small show of fairly good kankar is found in a zone 150 ft. X 15 ft. X 1 ft, About ½ furlong to the south of this, another small show of kankar occurs in a zone 100 ft. X 50 ft. X 1 ft.

(4) .Commencing from a point about 50 ft. to W.S.W. of T.P. 168/20 and extending upto milestone 359/3½ on the Bellary road is a small show of kankar in zone 300 ft. X 30 ft. X 1 ft.

(5) About 200-250 ft. north of the railway line between T.P. 168/20½ there is also a small show of kankar in zone 200 ft. X 3½ ft. beneath black cotton soil.

(6) Abutting the southern edge of the Bellary road near

road.....

milestone 358/2-3 there is a small show of kankar in zone 300 ft. X 150 ft. X 1½ft. ; here the kankar is found occurring on a high ground close to a water course. This is of fairly good quality. a sample of this kankar analysed:-

CaO	.....	48.80 per cent.
Fe_2O_3	.....	5.29 "
Al_2O_3	.....	2.89 "
MgO	.....	trace "
SO_3	.....	0.32 "
Insolubles	.....	7.86 "

(7) About 1½ furlongs SSE of Vadrahalli village (15° 14' 76° 28') there is a small show of poor quality kankar in zone 400Ft. X ½ ft.

(8) There is a small show of kankar in Ettinahatti village ((15° 7' 30" : 76° 37' 30") in zone 400 ft. X 150 ft. X 1 ft. To north-east of it at a distance of about ½ a mile on a nala front there is an occurrence of good quality kankar zone 500 ft. X 20 ft. 1 ft. There is also a small show ~~show~~ of kankar on the margin of a high ground about 1 mile ENE of Ettinahatti; this lies in a zone 300 ft. X 150 ft. X 1 ft. The quality is fairly good.

(9) Small patches of kankar capping schistose rocks have been found to the east of the Tornagallu -- Sandur road between milestones 21 and 23. These patches are usually 200 to 300ft. long by 100 ft. wide and about 1 foot thick.

(10) Nearly 2 miles south-east of Gollalingammanahalli village (14° 58' : 76° 40') on the east bank of a nala there is a narrow zone of kankar capping schistose rocks (epiriorite-schists) dipping at 60° to NNE. This zone is about 550 ft. X 80 ft. X 2 ft. (average). In places the kankar layer is about 4 to 5 ft. thick. The kankar is of good quality.

In all the above occurrences the kankar has been formed as a result of the calcification of the felspars of the gneisses and hence they are of varying degrees of purity.

(11) There is a low hillock of limestones at the head of a valley about 1½ furlong to NE of milestone (5) on the Samihalli--Santegudde road and about 7½ furlongs ESE of Gollalingammanahalli village. This limestone shows pseudo-bedding (practically horizontally-bedded) and has been perhaps, formed as a replacement deposit. It is found in association with epiriorite schists dipping at 35° N.E. Those limestones are only of limited extent and are confined to a small narrow zone 100 ft. by 120 ft. and about 30 ft. thick. In places the limestone 'beds' may be thick but the average thicknes is only 30 ft. Similar rocks are not to be found anywhere else within this area. The quality of the limestone appears to be faily good.

From the above catalogue of occurrences, it is obvious that the total quantity of good kankar or limestone within

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a 50-mile radius of this dam-site is very small and inadequate. On account of the varying character of the kankar deposits and the highly irregular and sporadic nature of their distribution in space it is difficult to make very accurate estimates of available reserves. But from the data available a fair idea of the total available quantities can be had and are given below:-

(1) On either side of the M. & S.M. Railway line to Bellary:

Between T.P.	168/6 and 168/14	72,765	c.ft.
" "	168/20 " Bellary road..	15,000	"
" "	168/20½ " 168/21½	12,000	"

(2) On the Bellary road:

Between milestones 358/2 and 358/3	...67,500	"
Near Vadrahalli Village	...60,000	"
(3) Near Ettinahatti Village	...45,000	"
(4) Near Gollalingammannahalli village:		
Kankar 88,000 c.ft.) 'Bedded limestones' 360,000 c.ft.)	448,000	"
Total	720,265	c.Ft

The occurrences on the Tornagallu-Sandur road between milestones 21 and 23 have not been estimated, but are not believed to carry more than 2,000 to 3,000 tons in all.

Since 45 c.ft. of this kankar go to make the long ton of 2,240 lbs., from the above list it is obvious that without allowing for losses in quarrying an transport, only about 16,000 to 19,000 tons could be had from all the known sources. If 25 per cent allowance be made for losses in quarrying and in transport not more than 15,000 tons could be obtained from all known sources within a 50-mile radius of this dam-site and this quantity represents only a eighth of the total quantity that would be required here if it is decided to make use of lime-surkhi as the bonding medium. Apart from the question of inadequate quantities, it would also be difficult to assure of a standard quality of material, since the quality of the kankar is not uniformly good everywhere.

LIME SURKHI VERSUS CEMENT MORTAR.

Though the general design of the dam to be built here has been agreed upon, there is till some difference of opinion regarding a suitable mortar for constructing this dam. The Hyderabad Government Engineers wish to make use of lime-surkhi as the mortar. But from the foregoing account it would be obvious that the Madras Government Engineers could not think of utilising lime surkhi especially as there are not any large deposits of good quality kankar or limestone either near Hospet or near Gollalingammanahalli south of the Sandur State. Further for the manufacture of lime, good coal or charcoal is required. The only forests close to this site lie in Sandur State. In this State the following species of wood suitable for charcoal-making are found:

(i) Hardwickia binata

Acacia.....

(ii) Acacia catochu

(iii) Albizzia Amara

(iv) Anogeissue latifolia

(v) Chloroxylon Swietenei

(vi) Cassia fistula

The Annual yield of charcoal from all sources (including the Donimalai and Ramandrug forests) in the Sandur State is estimated ~~mated~~ to be about 1000 tons or 30,000 of bags of charcoal. The sale price of each bags of charcoal, is now about Rs. 3/- at the point of manufacture.

If lime-surkhi is to be employed as the mortar, about 5 million cubic feet of limestones would be required on the British side alone for the manufacture of lime. As it would require about 10 maunds of coal or about 32 maunds of firewood to burn about 100 cubic feet of limestone lumps, about 20,000 tons of coal or about 64,000 tons of firewood would be required for our purposes. It would be impossible to obtain this large quantity of fuel locally from Sandur State alone.

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In the circumstances the only alternative left to the Madras Government Engineers is to make use of standard cement mortar

In order to show conclusively that good standard cement mortar is in no way inferior to lime/surkhi mortar, 2 'bricks' of granite stone should be binded respectively with the 2 types of mortar proposed to be used and subjected for a prolonged period to the action of the Tungabhadra waters; this comparative study would also be of some academic interest.

Acknwledgement.

I have to thank Diwan Bahadur N. Govindaraja Aiyengar, Chief Engineer for irrigation (Special) for the arrangements made for my visit to this dam-site. I am much obliged to Mr. A.R. Venkataraman, the Superintending Engineer in Charge of the Tungabhadra Headworks not only for his ready help and co-operation in my work but also for the warm reception and hospitality extended to me.

GOVERNMENT OF MADRAS.
Abstract.

Mines--Geological Survey of India--A Note on the Tungabhadra damsite and project by Mr. S. Krishnaswamy Geologist, Geological Survey of India--Recorded.

DEVELOPMENT DEPARTMENT (J).

G.O.MS.NO.4993 dated/7.10.48.
Read the following.

From
~~Finance~~ the Director, Geological Survey of India, No.5413--M/1579(1), dated/28.8.48.

ORDER:

(Ms.) 4993 dated/7.10.48.

RECORDED.

(Sd.)

To The Board of Revenue.
To The Director of Industries and Commerce. } with a copy of report.
To The Special Chief Engineer (Irrigation).

R. Thiagarajan
OFFICE ASSISTANT
MADRAS RECORD OFFICE.

C.N.V.